4.D DISCUSSION

4.D.1 The composition of ceramics from Ephesos in the first half of the 1st millennium B.C.

The petrofabrics identified can be associated with primarily metamorphic, but also volcanic respective igneous geological environments or can relate to sedimentary rocks or alluvial sediments, as depicted in figure 64 below.

The defining components of the »metamorphic groups« are mostly represented by mica schists of varying grain sizes and by a diverse spectrum of accessories (often epidote). Besides the micaceous character of the clay paste, a calcareous groundmass is attested for one of the petrofabrics. Samples falling within the petrofabrics EPH-METAMORPHIC_04 and EPH-METAMORPHIC_05 are exceptionally fine-grained with mineral inclusions of quartz and muscovite almost exclusively. They have to be monitored more comprehensively as compositionally they are not diagnostic enough in order to conduct a definite provenance determination (cf. chap. 4.D.3). However, an association to a metamorphic geological landscape is plausible. Two petrofabrics do deviate as serpentinite have been identified as dominant rock inclusion. Principally, all samples could fit into the same geological landscape implying a mutual provenance.

Seven petrofabrics correspond to an environment of volcanic or igneous geology. The range of volcanic rocks attested in all relevant petrofabrics is limited and comprises mainly fragments of intermediate composition and a glassy groundmass, often being volcanic glass. The amount of volcanic rock fragments preserved varies considerably comparing the individual petrographic fabric groups, and in the case of, for instance, the petrofabric EPH-VOLC_03, an intentional addition of these coarse particles might be presumed. Concerning the nature of the identified rock fragments, most of the petrofabrics potentially might be associated with the same geological region, which evidently cannot be equalised with the Kaystros valley around Ephesos.

Petrofabrics pointing to an origin from sedimentary environments are very diverse in the spectrum of their aplastic constituents. The clay matrices can be either micaceous, ferruginous or highly calcareous, while for three of the six defined petrofabrics chert is the most diagnostic feature. Archaeological and mineralogical evidence both indicate different production sites in the Eastern Mediterranean.

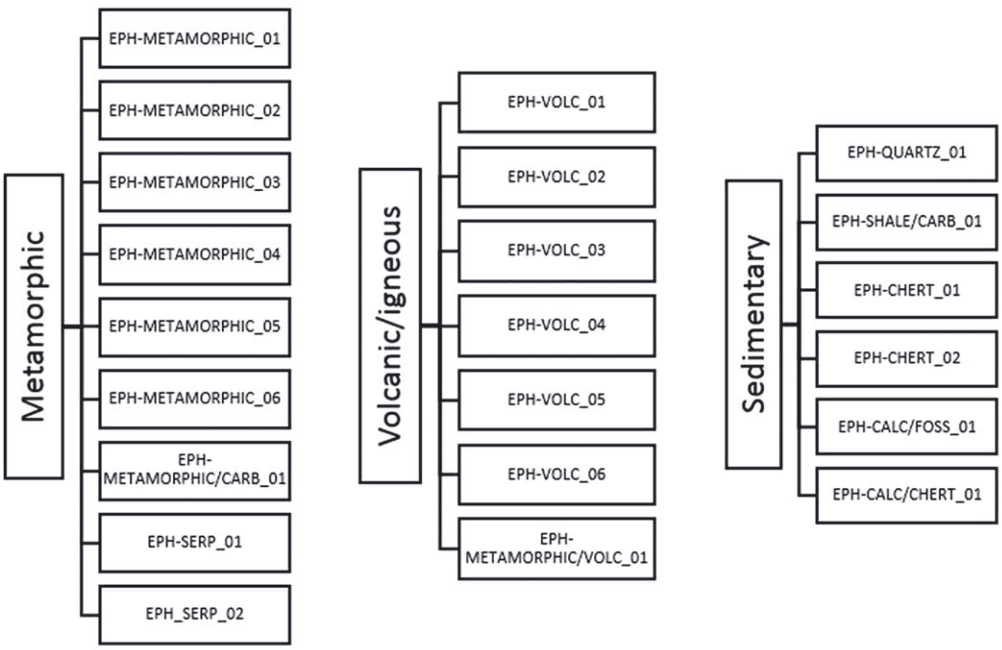

Fig. 64 Assignation of individual petrofabrics to metamorphic, volcanic/igneous and sedimentary environments

4.D.2 A local reference group? Pottery from the Archaic kiln on the Tetragonos Agora

Agreeably, as the most straightforward attempt to separate locally-produced ceramics from possible imports, the analysis of ceramics excavated in kiln contexts can be understood, providing that there is evidence the ceramics once constituted the load of this particular kiln. The analysis of such ceramic assemblages would demonstrate how much variability there can be expected in the composition and shape repertoire of vessels fired simultaneously or in a limited time span on one site. Debates on the organisation of pottery production concentrate on the possibility that certain potting groups might have shared firing installations for finishing their products rather than operating private kilns. The number of different clay recipes – reflected in the number of identified petrofabrics – detected in a kiln context, as such, might be equalised with the quantity of individual involved potting groups.

In the case of the Archaic kiln on the agora, the emergence of theories concerning the issues discussed above is hindered due to the archaeological record. The analysed samples contextually relate to stratigraphical units 96/196, 95/169, 95/271 and 96/179. These layers represent the ›fill‹ of the kiln structure associated to its abandonment or destruction at the end of the 7th century B.C.[1667]. It is arguable how reliably the ceramics can be directly linked to activities performed within this actual kiln having been fired in this installation, or if the fill of the kiln has rather the character of a midden used for the disposal of any vessels circulating in Ephesian daily life at that time.

Table 10: List of thin-sectioned samples from the kiln on the Tetragonos Agora

List of thin-sectioned samples from the kiln		
Kat.	**Petrofabric**	**Shape**
862	EPH-METAMORPHIC_04	Cup with everted rim
874	EPH-METAMORPHIC_04	Bowl (Grey ware)
876	EPH-METAMORPHIC_04	Plate
877	EPH-METAMORPHIC_04	Juglet
880	EPH-METAMORPHIC_04	Orientalising jug
890	EPH-METAMORPHIC_04	Amphora
892	EPH-METAMORPHIC_04	Deep storage vessel (Grey ware)
893	EPH-METAMORPHIC_04	Deep storage vessel
1847	EPH-METAMORPHIC_04	Bowl with steep wall
863	EPH-METAMORPHIC/CARB_01	Deep storage vessel
871	EPH-METAMORPHIC/CARB_01	Stand (Grey ware)
884	EPH-METAMORPHIC/CARB_01	Hydria
889	EPH-METAMORPHIC/CARB_01	Amphora (Milesian or Ionian type)
887	EPH-QUARTZ_01	Amphora (Milesian type)

The co-occurrence of three individual petrofabrics in the kiln context (cf. table 10) is attested, covering the defined groups EPH-METAMORPHIC_04, EPH-METAMORPHIC/CARB_01 and EPH-QUARTZ_01. Samples of these petrofabrics are particularly fine-grained and comprise a great diversity of vessel shapes.

A characteristic petrographic signature is difficult to establish for the petrofabrics under discussion. The petrofabric EPH-METAMORPHIC_04 contains mostly fine quartz and muscovite micas, while diagnostic accessory minerals and rock fragments are almost absent. Iron-rich opaque particles are being testified besides textural concentration features. Such a spectrum of minerals could be expected in locally-produced Ephesian ceramics. In one sample (**Kat. 1203**) traces of biotite-alkalifeldspar-epidote schist have been identified – a metamorphic rock well

[1667] Discussion of the stratigraphy in chap. 1.A.2, 1.A.3.3. and 1.A.4.

known from the geological landscape of Ephesos. A local provenance of this petrofabric would be realistic, but there is a certain complexity connected to the representation of vessel shapes in this petrographic fabric group. EPH-METAMORPHIC_04 as a whole[1668] includes several vessel shapes of Lydian type for which a local provenance is generally possible, but other production centres, foremost Sardis, and Ionian ones like Samos[1669] need to be considered as well[1670]. On the other hand, there are certain shapes that plausibly could fit into the local ceramic spectrum or Ionia, respectively. The archaeological evidence and the fact that fine wares of quartz-mica composition have been produced in several parts of Western Asia Minor implies that ceramic products of varying provenance have been subsumed in this petrofabric.

These observations are coherent with the other major petrographic fabric groups found in the kiln. EPH-METAMORPHIC/CARB_01 shares the presence of dominant fine quartz and muscovite with EPH-METAMORPHIC_04, but containing significant calcareous components such as micritic limestone. Again, an integration in the local geology of Ephesos is possible. A Lydian type vessel of Bichrome Ware, with high probability an import from Sardis or its vicinity, and vessels in Milesian style point to a co-existence of local production and imports, both from the North and the South, also within EPH-METAMORPHIC/CARB_01. Sporadic mineral inclusions of feldspar and pyroxenes could be used for arguing for a relation of at least some of the samples to a geological environment characterised by volcanic rocks. Parts of Lydia and Northern Ionia would fit these requirements.

One single sample from the kiln context falls within the petrofabric EPH-QUARTZ_01, which is almost defined by the presence of fine quartz exclusively, besides a few fragments of metamorphic rocks, carbonates and feldspars. Typologically it concerns an amphora of Milesian type. However, this does not prove its origin from Miletos, as there is still the chance of local reproductions elsewhere, including Ephesos. Rating from the range of aplastics preserved in this petrofabric, a provenance from Miletos[1671] cannot be excluded but this also applies to most parts of Western Asia Minor.

Petrographic data – due to the fineness of the clay pastes – and typological classification are both not exclusive for clarifying which analysed samples actually once might have been part of an original load fired in the kiln on the Tetragonos Agora, and which pieces, on the other hand, are imported wares only being deposited in this area when the ceramic workshop was abandoned. It can be assumed that a high amount of shards uncovered during the excavations of the kiln fill indeed might have been produced on site, as the petrographic profile would be applicable. More detailed conclusions and the reconstruction of modes of production need to be carried out.

4.D.3 Geochemical differentiation of fine-grained petrofabrics

Starting from the observation that some of the fine-grained petrofabrics are generic but seem to originate from different production sites and the fact that there are strong compositional analogies between the petrofabrics EPH-METAMORPHIC_04 and EPH-METAMORPHIC/VOLC_01, complementary geochemical analyses were initiated. 12 ceramic samples, which previously had been thin-sectioned, were submitted to the Fitch Laboratory of the British School at Athens[1672] for wave-length dispersive X-Ray Fluorescence analyses using a WD-XRF Bruker S8-Tiger spectrometer.

[1668] Cf. tab. 10.

[1669] Menelaou et al. 2016, 485 (»Fabric«).

[1670] For a comprehensive discussion cf. Kerschner 2005a, 136–139. See also the contribution by M. Kerschner in this volume (chap. 2.B.2.11).

[1671] Synchronic amphoras from Miletos studied by Seifert (Seifert 2004, 32) have been characterised as consisting primarily of quartz and micas besides few carbonates and accessories of epidote and pyroxenes.

[1672] Many thanks to the staff of Fitch Laboratory for the execution of WD-XRF analysis, conducted in the course of a Fitch Bursary Award.

When interpreting the results of these analyses, one needs to be aware of the small number of samples subjected to WD-XRF analyses. Particularly the statistical treatment is problematic, as the boundaries of the individual compositional groups cannot be defined reliably, as such being exposed to the risk of actually individual groups merging to only one compositional group. The graphs and the depicted ›groupings‹ should be rather understood as tendencies of provenance than a definite assignment to a production centre. Complemented by the petrographic information on the individual samples, the area of provenance might be confirmed or at least narrowed down.

The aim of this additional analytical programme was to test whether elemental homogeneity can be detected between samples that petrographically are grouping together but typologically indicate diverse provenance (this applies to the samples of the petrofabrics EPH-METAMORPHIC_04, EPH-METAMORPHIC_05, EPH-METAMORPHIC/CARB_01 and EPH-METAMORPHIC/VOLC_01). The sample selection for geochemical analyses was targeted and tried to integrate a range of possibly local vessels, but also shapes of Lydian type and Ionian/North Ionian/Aeolian pieces in order to see if they relate elementally to each other.

Table 11: List of samples analysed with WD-XRF

List of samples analysed with WD-XRF		
Kat.	**Petrofabric**	**Shape**
874	EPH-METAMORPHIC_04	Bowl (Grey ware)
1847	EPH-METAMORPHIC_04	Bowl with steep wall
2190	EPH-METAMORPHIC_04	Mug
2193	EPH-METAMORPHIC_04	Ovoid kotyle
2376	EPH-METAMORPHIC_04	Fruit stand marbled ware
2389	EPH-METAMORPHIC_04	Ovoid kotyle
2176	EPH-METAMORPHIC_05	Cup with everted rim
2328	EPH-METAMORPHIC/CARB_01	Myrina-Amphora bichrome ware
2145	EPH-METAMORPHIC/VOLC_01	Kotyle
2187	EPH-METAMORPHIC/VOLC_01	Cup with everted rim
2246	EPH-METAMORPHIC/VOLC_01	Small lid
2335	EPH-METAMORPHIC/VOLC_01	North Ionian black-figure krater

One assumption as being responsible for the ›mixed‹ character of the petrofabric EPH-METAMORPHIC_04 was its clear compositional analogy to EPH-METAMORPHIC/VOLC_01, apart from the additional presence of sporadic volcanic rock fragments/volcanic glass particles in the latter. Usually, mostly one or two small volcanic rock fragments have been noticed in EPH-METAMORPHIC/VOLC_01, which is the only distinguishing feature of its purely metamorphic counterpart mentioned above. The way a thin-section has been cut could, as such, have an impact on the presence/absence of volcanics, emphasising that some samples classified as belonging to the petrofabric EPH-METAMORPHIC_04 should be considered as possibly being related rather to EPH-METAMORPHIC/VOLC_01.

Of the elemental spectrum quantified by the WD-XRF analysis, values below 20 ppm had been excluded as well as elements that might have been influenced by post-depositional alteration. Finally, 26 major, minor and trace elements have been considered as meaningful for the Archaic ceramic samples (fig. 65). Two certified standard reference materials were analysed in order to test for the accuracy and precision of the instrument's performance. Before applying multivariate statistics, the raw data has been normalised and log-transformed (base 10 logarithm).

Multivariate statistics have been conducted with IBM-SPSS Statistics 22 software, covering principal component analysis (henceforth PCA) and hierarchical cluster analysis.

The 26 representative variables (elements) were statistically reduced to two principal components, with the eigenvalue of Principal Component 1 being calculated as being 33.112 % and Principal Component 2 being 60.659 % of total variability. These new variables were plotted in a

Kat.	Na2O (%)	MgO (%)	Al_2O_3 (%)	SiO_2 (%)	P (PPM)	K_2O (%)	CaO (%)	TiO_2 (%)	V (PPM)	Cr (PPM)	Mn (PPM)	Fe_2O_3 (%)	Co (PPM)	Ni (PPM)
2145	1,58	2,46	17,02	60,42	1240,00	3,07	6,37	0,81	114,00	111,00	961,00	6,16	19,00	67,00
2193	1,15	3,63	22,35	52,11	982,00	3,97	4,16	0,89	167,00	178,00	960,00	10,53	29,00	112,00
2246	1,32	2,40	19,78	57,07	991,00	3,12	6,55	0,91	138,00	147,00	1390,00	7,44	25,00	126,00
2176	0,67	3,48	20,68	54,08	751,00	3,90	6,57	0,97	164,00	252,00	855,00	8,20	24,00	171,00
2187	0,91	3,15	18,47	56,40	812,00	3,60	7,04	0,74	117,00	230,00	654,00	7,26	21,00	159,00
2328	1,31	3,60	19,63	55,26	1332,00	3,94	4,95	0,88	146,00	199,00	907,00	8,40	26,00	152,00
2190	1,17	2,67	20,18	56,32	680,00	3,22	6,07	0,93	147,00	219,00	1095,00	7,94	26,00	157,00
2335	1,44	2,38	17,91	53,59	1151,00	3,14	7,86	0,86	143,00	173,00	1276,00	7,30	26,00	107,00
2376	1,30	3,57	22,60	51,70	954,00	3,92	3,90	0,88	177,00	175,00	936,00	10,85	30,00	107,00
2389	1,15	3,87	19,55	53,89	946,00	3,56	7,09	0,87	136,00	219,00	885,00	8,35	26,00	186,00
1847	1,30	3,61	19,45	47,95	1802,00	3,36	9,52	0,84	146,00	224,00	1732,00	9,16	35,00	153,00
874	1,79	3,61	21,44	47,67	1774,00	3,77	8,34	0,90	185,00	198,00	2357,00	10,36	50,00	133,00
Average	1,26	3,20	19,92	53,87	1118,00	3,55	6,54	0,87	148,00	194,00	1167,00	8,50	28,08	136,00
StDev	0,29	0,56	1,68	3,68	365,72	0,35	1,65	0,06	21,79	39,32	471,79	1,46	8,03	33,53

Kat.	Cu (PPM)	Zn (PPM)	Rb (PPM)	Sr (PPM)	Y (PPM)	Zr (PPM)	Ba (PPM)	La (PPM)	Ce (PPM)	Nd (PPM)	Pb (PPM)	Th (PPM)	Sum (%)
2145	45,00	137,00	137,00	248,00	32,00	198,00	776,00	44,00	85,00	36,00	47,00	19,00	**99,59**
2193	67,00	135,00	167,00	255,00	41,00	168,00	846,00	43,00	93,00	47,00	40,00	18,00	**99,88**
2246	46,00	141,00	145,00	239,00	36,00	204,00	846,00	47,00	89,00	43,00	65,00	22,00	**99,88**
2176	63,00	123,00	221,00	189,00	32,00	217,00	466,00	39,00	79,00	31,00	32,00	23,00	**99,61**
2187	49,00	102,00	186,00	196,00	42,00	169,00	506,00	45,00	95,00	49,00	26,00	20,00	**99,52**
2328	45,00	111,00	166,00	295,00	42,00	203,00	982,00	52,00	96,00	48,00	33,00	20,00	**100,09**
2190	60,00	120,00	152,00	187,00	32,00	206,00	568,00	44,00	79,00	43,00	40,00	17,00	**100,10**
2335	51,00	206,00	120,00	190,00	31,00	183,00	736,00	43,00	95,00	37,00	69,00	15,00	**96,03**
2376	55,00	137,00	166,00	249,00	42,00	158,00	766,00	44,00	102,00	44,00	34,00	19,00	**99,94**
2389	48,00	109,00	163,00	347,00	42,00	214,00	725,00	59,00	101,00	49,00	35,00	21,00	**100,00**
1847	76,00	119,00	129,00	312,00	40,00	177,00	792,00	52,00	103,00	44,00	29,00	17,00	**99,35**
874	79,00	147,00	139,00	238,00	49,00	183,00	802,00	60,00	131,00	57,00	19,00	22,00	**99,32**
Average	57,00	132,00	158,00	245,00	38,00	190,00	728,00	48,00	96,00	44,00	39,00	19,00	**99,44**
StDev	12,00	27,14	27,43	51,81	5,70	19,55	150,40	6,64	13,79	6,93	14,88	2,39	**1,11**

Fig. 65 Elemental composition of samples analysed with WD-XRF. Data normalized to 100 %

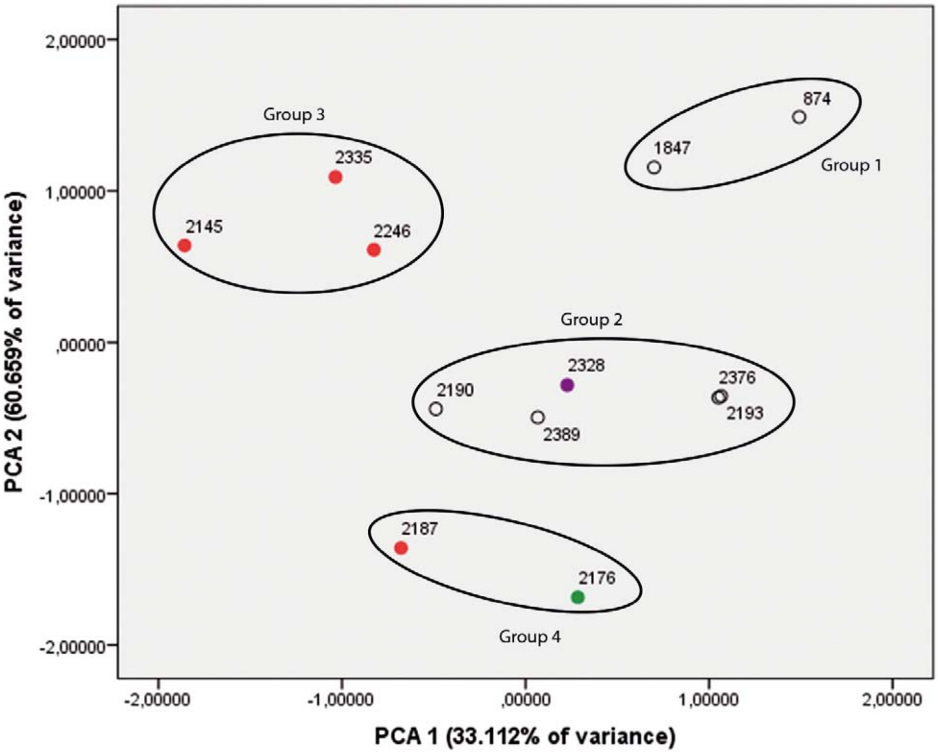

Fig. 66 Scatter plot depicting the first two principal components of the analysed samples. The colour-coding of the dots represents the different petrofabrics the samples had been assigned to in the course of thin-section analysis (EPH-METAMORPHIC_04 = white circles; EPH-METAMORPHIC_05 = green circle; EPH-METAMORPHIC/CARB_01 = purple circle; EPH-METAMORPHIC/VOLC_01 = red circles)

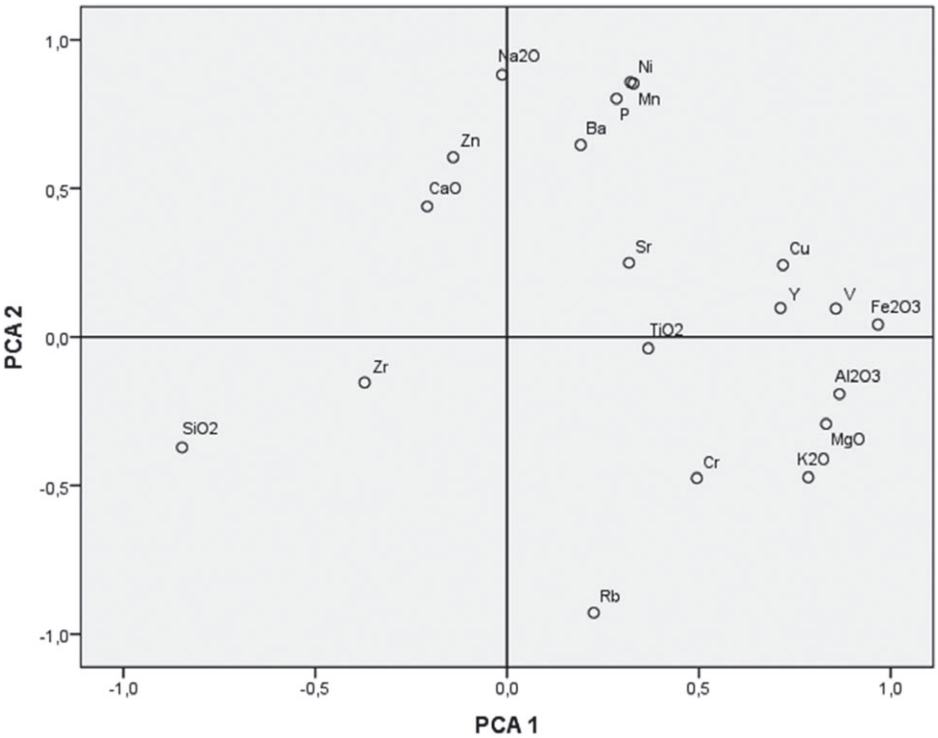

Fig. 67 Scatter plot highlighting the distribution of elements as they relate to PCA 1 and PCA 2

scatter plot illustrating the correlation of the 12 analysed samples on the basis of their elemental composition (fig. 66).

The distribution of the individual samples in the scatter plot results in the formation of a distinctive pattern. The colours chosen for the individual dots in the graph reflect the various petrofabrics. Four groups can be distinguished: most samples cluster together in Group 2, being the core group of the sample. Group 1 geochemically clearly stands apart from the core group, including samples **Kat. 874** and **Kat. 1847** of the petrofabric EPH-METAMORPHIC_04. Both samples originate from the Archaic kiln context on the Tetragonos Agora, for which possibly a local provenance might be assumed. Their distinctive elemental fingerprint with an increased value of Ni, Mn, P, Ba and Sr, as indicated when comparing the vectors in the loading plot in figure 67, might argue for their manufacture in Ephesos.

Group 2 includes the remaining samples of the petrofabric EPH-METAMORPHIC_04 with the ovoid kotylae falling within this group. The initial idea of samples of the petrofabric EPH-METAMORPHIC_04 coming from at least two different production centres seems to be confirmed, as their elemental fingerprint shows no relationship between Group 1 and Group 2. Considering vessels of Group 1 as local, Group 2 needs to be interpreted as being constituted with imported ceramics. Elementally in concordance with the vessels of Lydian type subsumed in Group 2 is the sample **Kat. 2328** (an amphora of Myrina-type) of the petrofabric EPH-METAMORPHIC/CARB_01, highlighted in a purple colour. The presented geochemical evidence might encourage the archaeological interpretation of these vessels as being foreign, possibly indeed Lydian, products.

In Group 3, three of the four samples of the petrofabric METAMORPHIC/VOLC_01 constitute a symptomatic cluster, being defined by an increased Zn and CaO ratio. In fact, petrographically these samples have been classified as imported vessels due to the presence of volcanic rock inclusions. One of the samples, **Kat. 2335**, has been described as North Ionian black figure krater. It needs to be considered that for all samples clustering in Group 2 a Northern Ionian origin might be probable.

Finally, Group 4 with the sample **Kat. 2187** of the petrofabric EPH-METAMORPHIC/VOLC_01 and the sample **Kat. 2176** of the petrofabric EPH-METAMORPHIC_05 can be correlated based on their elemental composition, with characteristically high Rb-values. Without doubt, this elemental signature points to another provenance from that of the other groups generated by PCA. Typologically the vessels are represented by cups with an everted rim.

The principal component analysis clearly verified that for the fine wares excavated in Ephesos, more than one region of provenance can be reconstructed. The areas around Çandarlı, Phocaea, Smyrna and Çesme had been referred to as possible production areas for the Archaic ceramic assemblage based on the petrographic analysis. Published WD-XRF reference data is accessible for Ephesos, Çandarlı and Pergamon, the last two being representatives for the North Ionian respective Aeolian landscape. However, this data has been gained from Hellenistic and Roman ceramics by S. Zabehlicky-Scheffenegger and R. Schneider, or R. Schneider and S. Japp[1673]. Reference data from Ephesos was available through the analysis of so-called Ephesian Grey Ware, also performed at the Fitch Laboratory. This is a ceramic ware well known to have been manufactured in Ephesos in the Early Imperial period. It was not possible to consult any WD-XRF results of Geometric or Archaic fine wares from the Ionian landscape that would have been most appropriate for comparison.

[1673] Zahbelicky-Scheffenegger – Schneider 2000, 112 state in their X-Ray Fluorescence Analyses on Late Hellenistic and Early Imperial period applique wares data for Ephesian and Pergamenian reference groups, as well as publishing data on applique wares of certain Ephesian provenance. Schneider – Japp 2009, 301 published the average elemental composition for the Pergamenian main geochemical group, one sub-group and reference data from Çandarlı.

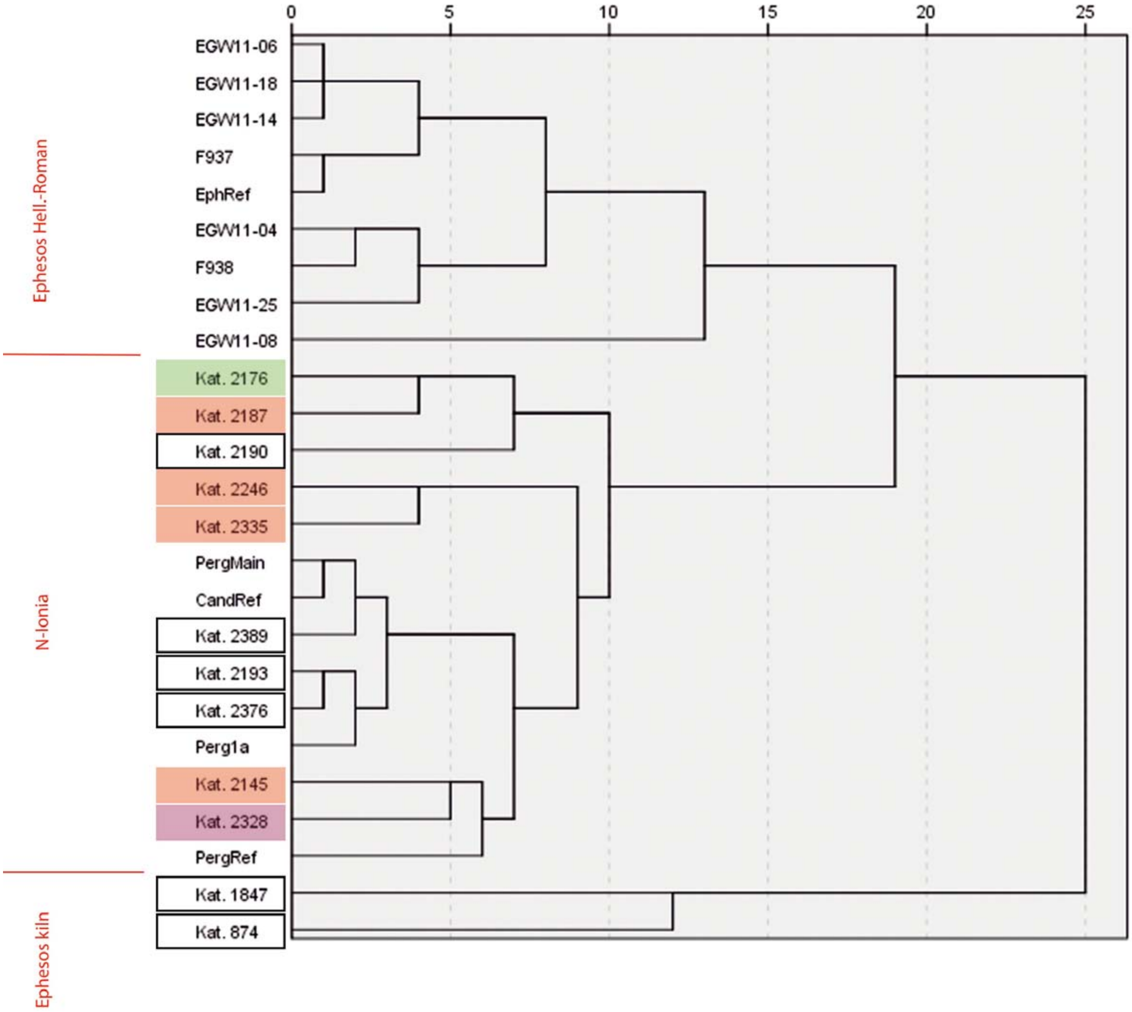

Fig. 68 Dendrogram generated by hierarchical cluster analysis based on the elemental composition of the analysed samples and reference materials

The hierarchical cluster analysis on non-log-transformed data including 20 elements[1674], using average linkage and Euclidean distance, created the dendrogram depicted in figure 68. The dendrogram represents the hierarchy of the individual samples as inferred by their elemental composition. The more branches split when moving down the hierarchy, the less the samples are geochemically related.

The branches, as such, represent the distance between the individual samples. For samples that cluster together the tightest, a similar provenance might be considered. Samples are again colour-coded referring to their initial grouping into the petrofabrics.

Interpreting the dendrogram, one major tendency is obvious. Samples **Kat. 874** and **Kat. 1847** retrieved from the Archaic kiln in Ephesos do not correlate to the rest of the analysed samples at all. Looking at the other main branch, it splits again into two branches. One of them, which appears uppermost on the graph, is represented exclusively by samples for which already an Ephesian provenance has been determined: it covers the Hellenistic-Roman Ephesian Grey Ware samples (EGW11-04. EGW11-06. EGW11-08. EGW11-014. EGW11-018. EGW11-25), two

1674 Twenty elements as published in the studies by Zabehlicky-Scheffenegger – Schneider 2000 and Schneider – Japp 2009 have been included in statistical analysis. All elements tabulated in tab. 11 have been applied for hierarchical cluster analysis, except Co, La, Ce, Nd, Pb and Th.

samples of Applique wares published by S. Zabehlicky-Scheffenegger and H. Mommsen (F927 and F938) and one reference group from Ephesos[1675]. The reason why this local group does not cluster together with the samples from the Archaic kiln might be the exploitation of different clay raw material sources in each period, their elemental composition slightly varying.

The other branch splits into several variables. Noteworthy is that several samples of the petrofabrics EPH-METAMORPHIC/VOLC_01 (red boxes), EPH-METAMORPHIC_04 (white boxes) and the sample falling within EPH-METAMORPHIC/CARB_01 (purple box) cluster not directly, but closely together with reference samples from Pergamon and Çandarlı[1676]. It is primarily the vessel shapes of Lydian type showing these compositional analogies to clays geologically being native to this Northern Ionian/Aeolian region. Strong political contacts of the Mermnad dynasty based in Sardis (Lydia) with the Ionian cities might have had an impact on the reproduction of Lydian-inspired shapes in Northern Ionia.

Of the remaining samples, **Kat. 2246** and **Kat. 2335** can be understood as one group, hierarchically being slightly separated from the before-described group, but still being partly related. The latter sample follows the shape repertoire of an North Ionian black figure krater. Considering the archaeological evidence and the relative geochemical proximity to clays of the Pergamenean territory, an North Ionian origin might apply to these two samples as well.

Lastly, **Kat. 2176**, **Kat. 2187** and **Kat. 2190** need to be evaluated. They correlate more to the proposed North Ionian samples than to Ephesian products. One sample, **Kat. 2176** is a cup with everted rim, one of the samples, **Kat. 2187** petrographically points to a volcanic environment of origin, following the possible North Ionian group as described before. Though the Ionian bowl **Kat. 2176**, from a typological perspective, could be integrated rather into the Southern Ionian cultural area, through geochemical analyses, its provenance from the Northern Ionian landscape has been attested.

In summary, the hierarchical cluster analysis supported the tendencies already gained through PCA, with the samples from the Archaic kiln most likely being local products and the rest of the samples clearly differentiating, demonstrating the heterogeneity of the ceramic spectrum circulating in pre-Hellenistic Ephesos. While PCA was able to explain the elemental peculiarities of the individual compositional groups, the hierarchical cluster method was able to firstly, show the relative distance between the ›foreign‹ samples, and secondly, to prove a relationship to the geological landscape of Northern Ionia. The emergence of a cluster incorporating most of the 12 analysed samples and reference material from Pergamon and Çandarlı does not necessarily mean that our samples do indeed originate from those two sites. As the whole region around those sites is defined by clays of a quite homogeneous elemental signature, a broad area in Northern Ionia might be considered as the production locality[1677].

Even though exemplarily just a small number of 12 samples have been analysed geochemically, the data generated allows us to make conclusions about the bulk of the samples, as demonstrated. Methodologically of enormous interest is the proof of how problematic the interpretative value of thin-section analyses of fine wares can be. Petrographic analyses were partly unable to differentiate local from imported products, emphasising the significance of integrated multidisciplinary studies.

[1675] Average geochemical composition of Ephesian ceramics (»Ephesos-Referenzgruppe« as published by Zabehlicky-Scheffenegger – Schneider 2000, 112).

[1676] »PergRef« describes a geochemical reference from the Pergamon-Ketios valley presented in Zabehlicky-Scheffenegger – Schneider 2000, 112 (Pergamon – Ketiostal). The other three reference samples had been published by Schneider – Japp 2009, 301. The abbreviation »PergMain« written in the graph means Gruppe 1 (Pergamon Hauptgruppe) referring to Schneider – Japp, »Perg1a« is Gruppe 1a (Pergamon Nebengruppe) and »CandRef« is synonymous with Gruppe 2 (Çandarlı) presented by Schneider – Japp 2009.

[1677] XRF-data on Archaic East Greek pottery has been published by Dupont (e.g. Dupont 1986). However, a different range of elements had been measured than in our case study.

4.D.4 Varieties of Ephesian petrofabrics and shape repertoire

Coarse wares are compositionally more representative and as such their Ephesian provenance can be determined more securely through thin-section analysis (diagram 102). In-depth geological investigations of the Menderes Massif or the Cycladic Metamorphic Complex the Selçuk area relates to, highlighted the abundance of high pressure metamorphic rocks in this region. Mica schists, gneiss and marble constitute the major rock types[1678]. Detailed mapping by Çakmakoğlu[1679] identified, moreover, quartz schists, phyllites, sporadic metavolcanics, dolomite and schists of biotite-quartz-epidote ± amphibole ± chlorite ± muscovite composition in the immediate vicinity of the archaeological site[1680]. Around today's Selçuk and to its east, similarly composed schists have been recognised, including additionally the minerals tremolite/actinolite and garnet[1681].

The typical mineral and metamorphic rock assemblage of Ephesian pottery is represented through the petrofabric EPH-METAMORPHIC_01, with coarse quartz-mica schists and mica/muscovite schists dominating. Characteristically, schists of quartz + biotite + epidote + alkali-feldspar/albite composition, moreover, underline the distinctive petrographic signature of local clays. It has to be stressed that, even though being coarse-grained with rock fragments of high angularity, this is a natural clay paste not having been manipulated intentionally by the potter. There is a clear preference for the utilisation of the petrofabric EPH-METAMORPHIC_01 in the production of cooking pots, but also for pithoi or roof tiles[1682]. The advantage of this coarse clay paste rich in quartz-mica schists is its performance properties. The high silica content of the metamorphic rocks that are natural constituents of the sediment considerably improved the heat resistance and thermal conductivity, favourable for cooking vessels. Furthermore, the coarseness of the clay paste enhanced the stability of pots such as in case of the pithoi. This petrofabric has been widely applied since the prehistoric (Neolithic) periods irrespective the intended function of the vessels[1683]. In the Archaic period, in contrast, there seems to be a specialisation on a limited spectrum of shapes serving recognisable cooking practices and, as such, the choice for

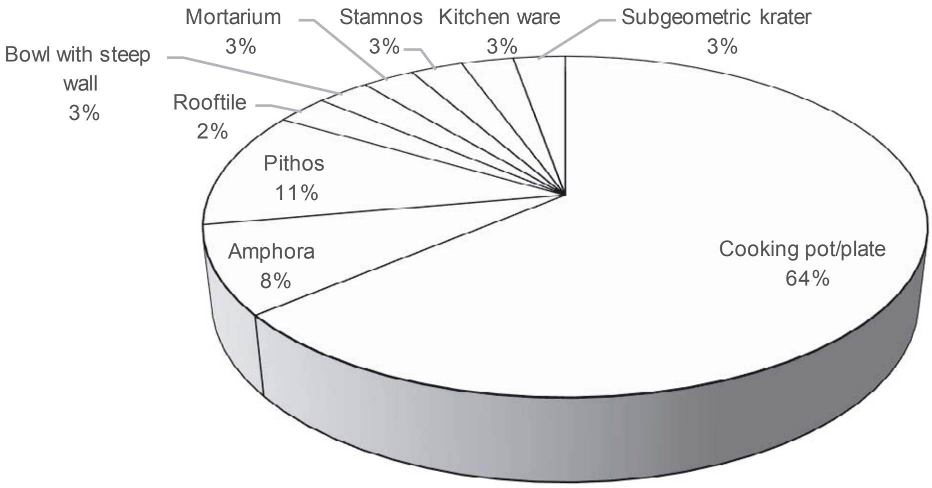

Diagram 102 Percental representation of local Ephesian ceramic types

[1678] Okay 2008, 31.
[1679] Çakmakoğlu 2007, 5–10 separates the region around Ephesos in the geological landscapes of »Efes Nappe« and »Şirince Metaflysch«.
[1680] Çakmakoğlu 2007, 6.
[1681] Çakmakoğlu 2007, 9.
[1682] Cf. also Sauer 2004, 63 f. (»Ziegeltyp A«).
[1683] Peloschek 2017.

this particular clay paste is selective[1684]. The petrofabrics EPH-METAMORPHIC_02 and EPH-METAMORPHIC_03 are coherent with the above-described clay paste, but differ slightly, as for the former, an increased epidote content is obvious while the latter contains a higher quantity of infilled feldspars/albite[1685] compared to EPH-METAMORPHIC_01. Natural variability is responsible for these variations as an effect of the extraction of the clay from different – yet possibly closely located – clay mining areas.

Constantly, amphoras have been manufactured from a specific local clay in the Archaic period. The petrofabric EPH-METAMORPHIC_06 is defined by distinctive textural concentration features in a variety of colours ranging from yellowish to reddish-brown, besides micas and quartz. The sample size of analysed specimens is too small to prove if such a composition is indeed only represented by amphoras.

Two petrofabrics (EPH-SERP_01 and EPH-SERP_02) relate to serpentinite. This metamorphic rock is common around Ephesos and has been documented particularly to the southeast of Selçuk. Studies on Ephesian ceramics were already able to demonstrate that serpentinite in different stages of oxidation (ranging in XPL from a greyish to a strong orange colour) are widely distributed in the region and indicative of the local pottery. Only one single sample falls within the petrofabric EPH-SERP_01, having been identified as a subgeometric krater. It is surprising that one of the earliest samples analysed has been formed of this clay paste which stands in a tradition that goes back to the Late Chalcolithic period. Similar observations apply to the petrofabric EPH-SERP_02, containing besides serpentinite fragments additional talc. This petrofabric is of interest as an alteration of serpentinite to talc is visible in the clay paste constituents. Functionally, this petrofabric shows a strong correlation to utilitarian ware, comprising pithoi and cooking pots.

The clay pastes utilised are quite homogeneous and reflect strikingly the most common clay raw materials available. A certain unity concerns also the vessel shapes that can be associated with these local coarse wares, as illustrated below.

4.D.5 On the provenance of imported vessels

A high amount of imports has been identified (diagram 103), their composition not being in concordance with the local geology around Ephesos. Firstly, imported vessels will be discussed, for which a secure provenance determination has been achieved followed by more problematic non-local pieces.

Four petrofabrics indicate an association with the island of Cyprus, namely EPH-CHERT_01, EPH-CHERT_02, EPH-CALC/FOSS_01 and EPH-CALC/CHERT_01. Their distinguishing feature as being imported wares is the presence of (radiolarian) chert and micrite embedded in a calcareous clay matrix. Diagnostics are, moreover, occasional pyroxenes and volcanic/basaltic rock fragments and other intermediate volcanic rocks as well as serpentinite. The petrofabrics EPH-CHERT_01, EPH-CHERT_02 and EPH-CALC/CHERT_01 fit very well into the geological landscape of Cyprus, as chert is testified on several spots all over the island. As such, a similar provenance might apply to these three petrofabrics but cannot be established with certainty. Areas around the Troodos massif and to its south or southwest (the Mamonia complex, close to Paphos) have to be considered as landscapes accommodating possible production sites, as this area is defined by abundant outcrops of radiolarian chert[1686]. However, the Kyrenia Terrane dispersing in the whole northern coastal area of Cyprus might be a more probable environment that the ceramics from Ephesos might originate from. A combination of limestone, marl, chert,

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1684 However, more analyses on a broader spectrum of vessel shapes would be required in order to test this assumption.

1685 Infilled alkalifeldspar/albite had been noted by Sauer – Waksman 2005, 5 as a common constituent of Ephesian clays.

1686 Dikomitou-Eliadou et al. 2016, 455–456.

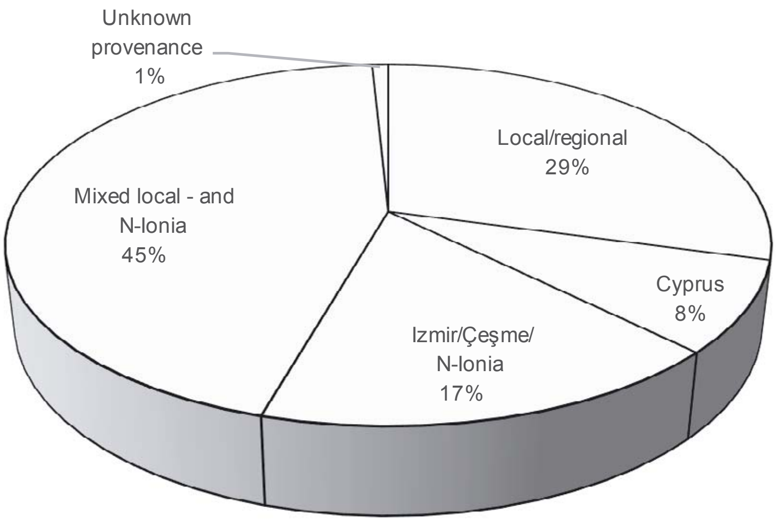

Diagram 103 Percental representation of analysed samples by provenance

radiolarian chert, basalts and micas[1687] found in this micro-region best matches the composition noticed for the mortaria. However, Cypriot workshops might have been specialised in the production of grinding bowls, as in the ceramic spectrum uncovered in Ephesos, only mortaria are represented. M. Spataro and A. Villing[1688] stressed the importance of Cyprus as a production centre of mortaria which were evidently distributed also to Western Asia Minor/Ionia in the Archaic period. The style of several of the analysed mortaria has been realised as being inspired in some elements by the common Cypriot shape repertoire, but petrographic analysis confirmed indeed their Cypriot origin coming to Ephesos as imports. The success of Cypriot mortaria as highly-demanded export goods in the Eastern Mediterranean has been explained on the basis of volcanic particles naturally embedded in the clays that should promote an improved abrasion-resistance of the vessels during the grinding activities[1689].

The petrofabric EPH-CALC/FOSS_01 can be assigned to Cyprus as well, its calcareous clay matrix and high amount of different species of (planktonic) foraminifera matching properties of clay pastes being native to the island[1690]. A Cypriot provenance has already been stated through typological studies, following the decoration of Cypriot vessels.

The most extensive number of analysed samples excavated in Archaic contexts in Ephesos and being identified as imports (the petrofabrics EPH-VOLC_01 to EPH-VOLC_06 and EPH-METAMORPHIC/VOLC_01) is directly related to a landscape of volcanic activity or influenced by or exposed to volcanic events. Generally, the volcanic rock fragments detected in all relevant petrofabrics are homogeneous with extrusive rocks of intermediate to rarely acidic composition, are a diagnostic feature. Rhyolite, dacite or andesite might be reconstructed as possible parent rocks; in the case of the petrofabric EPH-VOLC_02 a trachyte needs to be considered as well. Usually the bulk of these rock fragments are rather volcanic glass, being defined by very small and vitrified mineral grains surrounded by an isotropic groundmass. Mineral grains embedded in the clay matrices of the ceramics also support the association with a volcanic environment, as zoned plagioclase phenocrysts (EPH-VOLC_03) and K-feldspar phenocrysts (EPH-VOLC_04), as well as loose particles of sanidine, plagioclase and K-feldspars testify. Regarding the petro-

[1687] See Pantazis 1979 for more details on the geology of the region.
[1688] Spataro – Villing 2009.
[1689] This model had been proposed for explaining the import of mortaria in the 8th and 7th c. B.C. from Cyprus to the Levant by Zukerman – Ben-Shlomo 2011, 88.
[1690] Dikomitou 2007, 113 f. describes an identical clay paste for Deneia, located to the west of Nicosia.

fabric EPH-METAMORPHIC/VOLC_01, EPH-VOLC_01 and EPH-VOLC_06, a possible additional metamorphic component had been detected (see below).

Distinctive analogies observable within the ›volcanic‹ petrographic fabric groups might indicate that they derive from broadly the same or a very restricted geographical area. Following the typological classification of the sampled vessels, the whole Ionian and Northern Ionian, but also Lydian and Aeolian landscapes need to be considered as possible production localities, challenging the validity of the petrographic data. Based on published petrographic and geological studies, the area covering Çandarlı in the north to the immediate area south and southwest of Izmir, including the Aegean islands of Samos and Chios, needs to be scanned for eligible references.

Outcrops of volcanic rocks of matching composition most closely positioned to Ephesos are being located in the Yeniköy area near Izmir and the Çeşme and the Karaburun peninsula. Geologically this area can be equalised with the so-called Bornova Flysch zone with carbonates of respectively limestone and mafic volcanic rocks dominating[1691]. Rhyolite, rhyodacite and varieties of andesitic rocks have been noticed between Izmir, Seferihisar and Urla. Following the descriptions by M. Akartuna, there exist pyroxene-andesites and andesites of augite-biotitite-opaques composition. Rhyolite of this area is characterised by a vitreous matrix similar to our petrofabrics, while containing phenocrysts of sanidine, quartz and biotite[1692]. Formations of Miocene dacite, rhyolite and rhyodacite geographically nearest to Ephesos are known from the area northeast of modern Doğanbey. Andesite can be found abundantly in the Çeşme peninsula[1693] and the preliminary analysis of prehistoric ceramics from Liman Tepe[1694] – synonymous with the Ionian city of Clazomenae – verified the use of andesitic and basaltic clay pastes in local and regional pottery production.

The petrofabrics EPH-VOLC_02 and EPH-VOLC_04 can be classified as rhyolitic/trachytic respectively, being defined by the presence of volcanic glass for the latter. As discussed above, this composition might apply to clays from the Çeşme-Izmir/Smyrna region or reaching also further northwards to Phocaea and Çandarlı. The cooking plate and orientalising pithos represented in these petrographic fabric groups do not add more information to pinpoint potential production sites.

Several features noticed in our volcanic samples have been finalised already by other petrographers. J. Riederer describes Archaic pottery retrieved during excavations in Didyma as so-called Glimmerware, which is a highly volcanic clay paste[1695]. It in its main components correspond to EPH-VOLC_03 and EPH-VOLC_05, containing besides plagioclase phenocrysts and pyroxenes also tuff. Not tuff, but pumice had been identified in the petrofabric EPH-VOLC_03. Nonetheless, Riederer was tempted to set this clay paste, which rarely occurs in Southern Ionia, in relation to a production centre on the island of Aegina in the Saronic Gulf. One argument for this possible assignation focused on the shape repertoire of the analysed vessels, being represented by cooking pots. Aegina is a prominent producer of cooking pots from the first half of the 7th century B.C. onwards, according to G. Klebinder-Gauß[1696]. The local geology of the island, moreover, is defined by pyroclastic formations of andesitic composition, but also dacite and basalts are widely exposed. Based on the analysed ceramic assemblage from Ephesos and having noted their compositional relationship I would, however, rather argue for an Anatolian provenance. Coarse wares found in the Levant and being defined by andesitic inclusions have already been linked to a production in Northwest Anatolia[1697] without further specifying a workshop area. Based on our petrographic data and comparable references from the region, an origin

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1691 Moreover, serpentinite and radiolarian chert complement the characteristic rock spectrum in this region, as summarised by Okay 2008, 30 f.
1692 Akartuna 1962, 12 f. Basalts are also native to the area.
1693 Location pinpointed through the geological map of the Izmir region by Şenel 2002.
1694 Ceramics of the Early Bronze Age have been briefly described by compositional means by Day et al. 2009, 341.
1695 Riederer 2007, 51 f.
1696 Klebinder-Gauß 2012, 173 f.
1697 Stager 2011b, 62.

from the broader area around Phocaea or spreading towards the Izmir region might be assumed for the petrofabrics EPH-VOLC_03 and EPH-VOLC_05.

For the petrofabrics relating to both a volcanic and metamorphic environment, the area around Miletos and north of Izmir/Smyrna do most appropriately correspond to the described composition. M. Seifert mentioned the coexistence of volcanic components (sanidine, plagioclase, pyroxenes, volcanic glass, volcanics) and metamorphics (mica schists, gneiss) in the analysis of Archaic amphoras[1698]. These tendencies have been encouraged by Spataro and Villing[1699] when noticing a combination of volcanic tuff, amphibolite, basalt and mica schists or gneiss in pottery shards of Milesian provenance, but placing emphasis on the non-calcareous character of the local clay. Looking to Northern Ionia, again a combination of extrusive and intrusive rocks and metamorphics is common, specifically close to Phocaea and Çandarlı. The petrographic fingerprint of ceramics native to the landscape involves acid to intermediate volcanic rocks (rhyodacite and andesite with augite as main components, tuff), granitoids and feldspars (alkalifeldspar and plagioclase)[1700]. Schists and siltstone are, moreover, native to the region, but most significantly, limestones and, as such, associated carbonatic clay pastes are particularly well known[1701]. The archaeological evidence connected to the petrofabrics EPH-METAMORPHIC/VOLC_01, EPH-VOLC_01 and EPH-VOLC_06, seems to confirm a possible origin from Northern Ionia rather than from Miletos, making a provenance from the region around Çandarlı likely, also testified through the geochemical results.

There are two petrofabrics related to sedimentary rock and possibly alluvial deposits that cannot be related to a specific geographical area on the basis of the documented data. EPH-SHALE_01/CARB_01 might be associated with rock formations in the Bornova Flysch zone around Izmir and the Çeşme peninsula[1702], corresponding to its typological affiliation as Northern Ionian products. For EPH-QUARTZ_01, on the other hand, represented by an amphora of Milesian type, various production locations in Western Asia Minor might be considered.

The results of natural-scientific analysis might give the impression of imports detected in Archaic Ephesos exclusively originating from Northern Ionia. This tendency is directly related to the sampling strategy of the analytical programme: Southern Ionian imports can be more securely identified by typological criteria, and, thus, such vessel shapes have not been subjected to archaeometric investigations, and archaeological data is appropriate for their provenance determination alone. Referring to the archaeological interpretation, Southern Ionian products are well represented in the Archaic ceramic material from Ephesos.

1698 Seifert 2004, 32–35.

1699 Spataro – Villing 2009.

1700 Following descriptions by Slane – Kiriatzi 2014, 15 (igneous fabric; volcanic fabric).

1701 Compare the results of the analysis of Late Roman C-Ware by Ladstätter – Sauer 2002, 324. Albayrak – Özgüner 2013, 613 also mention rhyolites and limestone around Phocaea. Sauer – Ladstätter 20008, 185 in the course of the analysis of thin-sections from the Vediusgymnasium in Ephesos assumed that »Scherbentyp L«, which follows the composition described in the text, might originate from Çandarlı.

1702 Okay 2008, 30.